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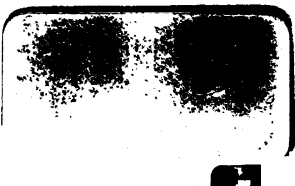
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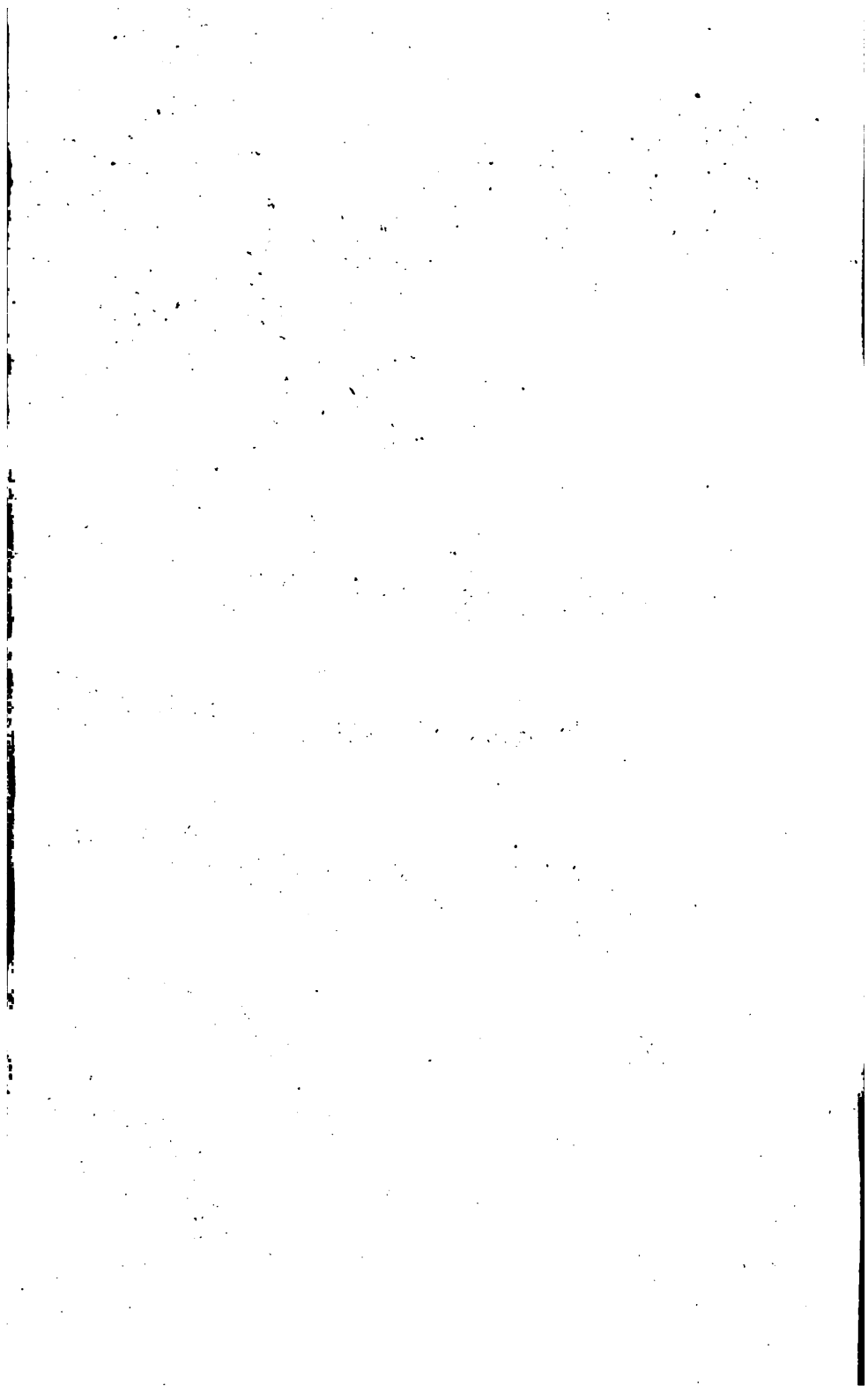
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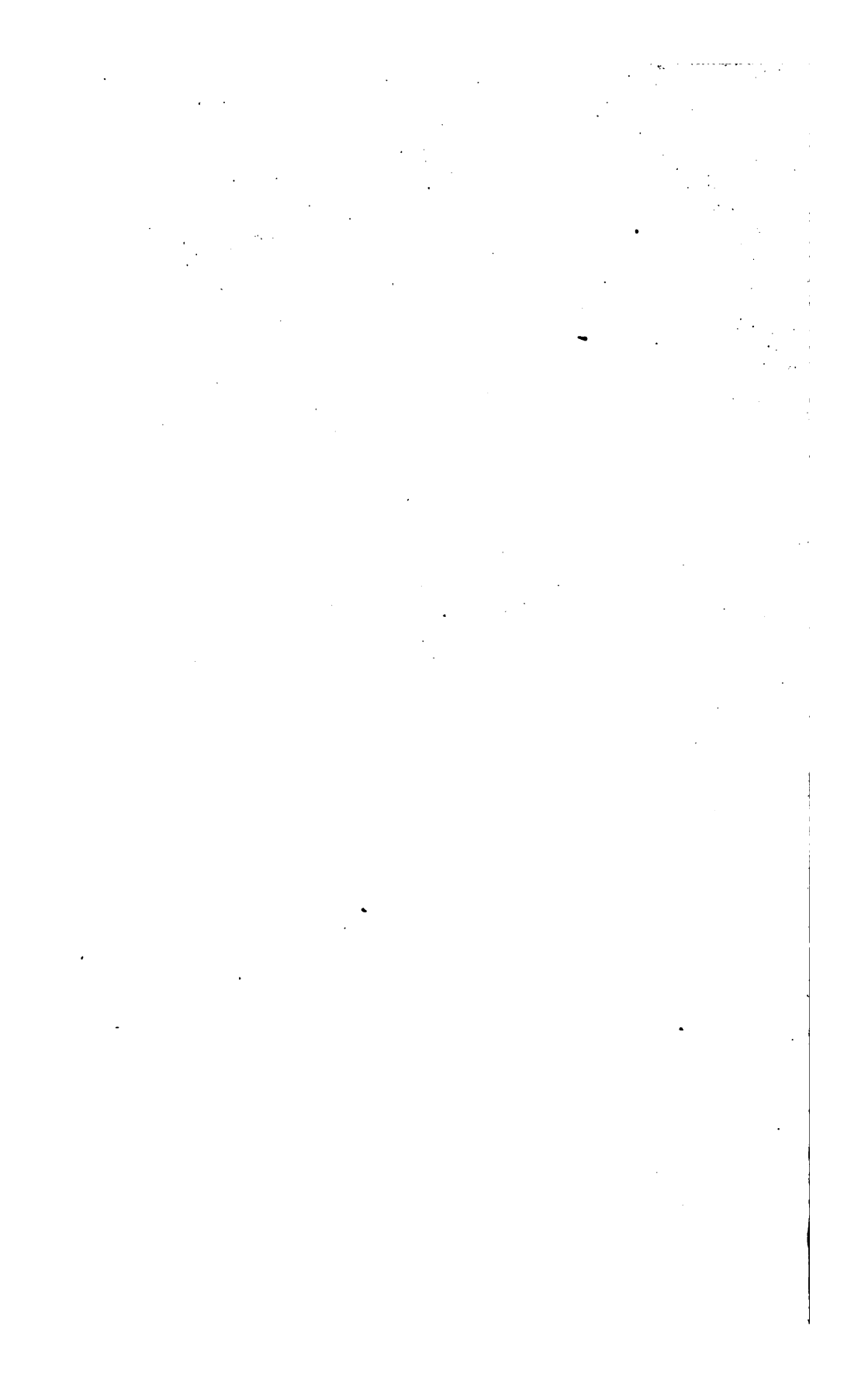
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ON
INCREASING THE DEPTH
OF
SOILS

BY CUTHBERT WILLIAM JOHNSON, ESQ.

BARRISTER AT LAW,

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LONDON:
JAMES RIDGWAY, PICCADILLY.

M.DCCC.XL.

933.



LONDON :

PRINTED BY BLATCH AND LAMPERT, GROVE PLACE, BROMPTON.

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THE favourable manner in which a considerable portion of the following pages has been received in the *Quarterly Journal of Agriculture*,* has induced its republication in a separate and enlarged form. Of the importance of the theme, I need hardly speak; for it is one with which is intimately connected the improvement of Agriculture, a science which never advances without increasing the wealth, and the happiness, of all branches of the community.

In thus again addressing the English Farmers, and detailing the result of my experiments and observations, I am anxious not to commit to them this little work, without expressing my gratitude for the kindness with which they have, on many former occasions, received my humble efforts to promote their increased prosperity.

14, *Gray's Inn Square*, Feb. 1840.

* Vol. x. p. 338.

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ON

INCREASING THE DEPTH OF SOILS.

THERE is, perhaps, no modern agricultural effort so important in its results, as the deepening the soil by mechanical means—an operation which may be effected by either spreading earth on the surface of the land, such as chalk, marl, clay, or sand, according to the composition of the natural soil ; or the quantity of the super-stratum may be still more easily and economically added to, either by the means of deeper ploughing, by the spade, or by the modern invention of the subsoil plough, upon which modes I propose to briefly remark in this work.

Considerable discussion has taken place, with regard to the advantages of subsoil-ploughing ; a difference of opinion which appears to have been principally caused by an inattention to the chemical effects produced by the subsoil, or Deanstonizing system of tillage, so named from being first employed, or at least first,

brought into general notice, by Mr. Smith, of Deanston, in Stirlingshire, when he was examined, in 1836, before the Agricultural Committee of the House of Commons. By this system, by means of a subsoil-plough, of which there are several kinds, the subsoil, or under crust of earth, is merely broken and pulverized, say to the depth of from fourteen to twenty inches, without being brought to the surface, or mixed with the upper soil; and after a lapse of four or five years, a portion of the previously disturbed substratum is found, by experience, in a state to be advantageously (by deep ploughing) brought to the surface; it being in this time, by the action of the atmosphere, and perhaps by a partial mixture with the surface-mould, rendered sufficiently friable and fertile. It is of necessity a consequence of this subsoil-ploughing, that the permanent drains of all lands thus cultivated must be constructed rather deeper in the soil than is usual with farmers: the top of those of Deanston are placed at a depth of twenty-two inches from the surface, so as to be completely out of the way of the subsoil which the plough has turned over.*

As the description of this valuable plough cannot be

* At the Netherby meeting, in September 1839, Sir James Graham said:—"By a recent discovery to which I attach great importance—I mean the discovery of deeper ploughing—I am satisfied that I have been misled myself, and have misled you, in laying the tile drains too shallow. I have of late laid the drains considerably deeper than I have been accustomed to do; the top tile is at least thirty inches below the surface, and I have done this for the purpose of introducing deeper ploughing."—*Brit. Farm. Mag.* v. iii. p. 458.

too generally circulated, I will here introduce it in Mr. Smith's own words.*

"The Subsoil Plough has been constructed on principles appearing the best fitted to break up the subsoil completely, to a depth sufficient for thorough cultivation, say 14 to 16 inches, whilst the active soil is still retained on the surface—to be of the easiest possible draught in reference to the depth of furrow and firmness of the subsoil—to have strength and massive weight sufficient to penetrate the hardest stratum—to resist the shocks from fast stones—and to throw out all stones under 200 lbs. in weight. All this has been accomplished and practically proved at Deanston, over an extent of at least 200 acres of various soils; and also in various parts of England, Scotland, and Ireland, during several seasons. The plough requires four good horses, an active ploughman, and a lad to drive the horses and manage them at the turnings. Six horses, yoked three and three abreast may be necessary in some very stiff or stony soils. A common plough, drawn by two horses, goes before the subsoil plough, throwing out a large open furrow of the active soil; the subsoil plough following, slits up thoroughly and breaks the subsoil, and the next furrow of active soil is thrown over the last opened furrow of the subsoil; the stones brought to the surface by the subsoil plough, being thrown aside on the ploughed part of the land by a lad, thus the work proceeds until the whole field is gone over. The lad should carry a bag of wooden pins, that he

* On Thorough Draining, and Deep Ploughing, p. 18.

may mark the site of the large fast stones which the plough cannot throw out, and which must afterwards be dug out with the pick, and perhaps blasted.

The charge of subsoil ploughing a Scotch acre may be estimated at 24s. or 30s. per statute acre, being one-fifth of what a similar *dépth* with the spade would cost, and upon the whole, as effectually done. When land which has been opened up by the subsoil plough shall have undergone the first rotation of cropping, several inches of the subsoil may be taken up by the plough to mix with the active soil, and in proportion as the subsoil is ameliorated, so may the greater depth be taken up with advantage. In the richer subsoils it is sometimes expedient to plough to the whole depth of the moved subsoil on the first application of the trench plough. The trench plough recommended for this process, should be made in the form of Wilkie's plough, having all its dimensions made of double size; or what is found to answer fully as well, by a plough in the fashion of the old Scotch plough, but also of double the dimensions. Such ploughs require six horses, yoked three and three abreast, with one man to hold the plough, and another to manage the horses, to do the work effectually. This operation should be performed in turning over the winter furrow preparatory to a green crop, and the sooner the work is performed after harvest the better. In estimating the expense of this operation, the horses may be charged at 4s. each, to cover all expenses, tear and wear, &c., which will amount to 24s.; two men 2s.=4s.; and an attendant

lad to pick out stones, 1s.; in all 29s. As the work is heavy, the motion of the horses is necessarily slow, and it will in general take eight hours' working to accomplish one statute acre. The expense of this operation may appear alarming; but when it is considered that one such ploughing will be more effectual in killing weeds, and in exposing the soil to the air, than two ordinary ploughings, we may deduct the cost of two such=20s., leaving 9s. to be charged against the deep working.

When land has been thoroughly drained, deeply wrought, and well manured, the most unpromising sterile soil becomes a deep rich loam; rivalling, in fertility, the best natural land of the country; and from being fitted for raising only scanty crops of common oats, will bear good crops of from 32 to 48 bushels of wheat, 30 to 40 bushels of beans, 40 to 60 bushels of barley, and from 48 to 70 bushels of early oats, per statute acre; besides potatoes, turnips, mangel wurtzel, and carrots, as green crops, which all good agriculturists know are the abundant producers of the best manure. It is hardly possible to estimate all the advantages of dry and deep soil. Every operation in husbandry is thereby facilitated and cheapened—less seed and less manure produce a full effect—the chances of a good and early tid* for sowing are greatly increased—a matter of great importance in our precarious climate,—

* "Tid," a Scotch term, for that state of the ploughed soil, which is most suitable for receiving the seed—neither too moist nor too dry.

and there can be no doubt that even the climate itself will be much improved by the general prevalence of dry land."

In this instance, as in most other novel agricultural efforts, the zeal of its promoters has sometimes carried them too far; they have even confidently contended that in most situations, subsoiling will render draining unnecessary; a result which would hardly have been arrived at by the most sanguine subsoiler, if he had paused to recollect that deepening the soil, however it may promote the absorption of atmospheric moisture, can in few situations enable land springs, and stagnant waters, to escape. The objects to be obtained by these operations are, in fact, diametrically opposite. The one is adopted to increase the gradual healthful supply of food and moisture by the earth to the roots of the crop, in the degree the most grateful to its habits. The other expensive practice is, to remove that moisture, when (from whatever cause) it becomes too abundant for healthful vegetation; and this removal can only be obtained in very peculiar situations, by the mere use of the subsoil-plough, and that to a very limited extent; such, for example, as when the crust or subsoil, is of such a degree of thinness as to be completely penetrated by the plough; and thus the upper soil, brought by breaking up the separating crust, into immediate contact with a substratum of earth, of greater water-absorbing properties than the pan-crust, which has hitherto separated them.*

* At the Manchester Agricultural Meeting in October 1839, Mr.

I propose, in this work, to examine first, what is the chemical effect of the atmosphere upon the broken-up subsoil; secondly, how that substratum is thus rendered more serviceable to the plants growing upon it; and thirdly, the testimony of practical farmers, which has been produced on the question. In entering on the investigation, I will suppose, for the sake of the argument, what is pretty commonly the case, that the chemical composition of the subsoil, and that of the surface mould, is chemically nearly the same, each

Smith observed that "the subsoil plough had not only been efficacious on his own farm, but the use had extended over many counties in England, Scotland, and Ireland, and it had even been introduced into the stubborn soil of the West Indies. He knew many instances of its success on light, gravelly, and moory soils: he mentioned one instance where it had been tried on such a soil in Perthshire, which consequently produced one of the most splendid crops of barley ever grown in that county. He had also letters from farmers who had tried the plough upon all bottoms—chalky, flinty, gravelly, and moory bottoms, level soils, stiff clays, and almost every variety of subsoil found in these islands—and without one single instance of failure. He was frequently asked as to the propriety of using his plough before draining: and he would say that if the ground was completely drained by nature, by its resting on a gravelly or sandy bottom, then the subsoil plough might be safely, and with advantage used at once; but if the bottom were clay, or any stiff hard subsoil that retained the moisture, then the subsoil plough must be withheld till the land had been drained, because its application but made a greater space to hold water.—*Brit. Farm. Mag.* v. iii. p. 450. "The subsoil plough," says the Rev. W. Rham, "does wonders in lands which have a porous subsoil, even when employed *by itself*; but unless its application on stiff wet lands be accompanied *with draining*, it makes them worse, keeping in the water which would otherwise run off the surface."—*Journal of Eng. Ag. Society*, vol. i. p. 262.

containing very similar proportions of the earths silica, alumina and carbonate of lime, and that the surface-soil possesses merely the largest portion of decomposing organic remains. And yet, although this conclusion is one that is very usually correct, yet it is by no means universally the fact; for not only does this dissimilarity of composition, in many cases, appear on a chemical examination, but the practice of many farmers supports the results of a chemical analysis; thus the spade cultivators find, almost always, the advantages of trenching the soil, and in most districts, "a thin-skinned soil" is but another way of describing its poverty. Then again, the farmers of the chalky soils of Sussex, Dorsetshire, Wilts, and Hampshire, very advantageously raise the substratum of chalk, existing under their lands, and spread it in considerable quantities on the surface. The farmers of Essex and Suffolk in many places do the same with the under stratum of clay or marl on which their surface-soils immediately rest; and they find this a very profitable practice, because the earths, which constitute all fertile soils, being also the necessary constituents of the commonly cultivated grasses, are gradually and incessantly carried off from thence by continual cropping, and consequently in time an advantageous opportunity is afforded for their being replenished with the earths, perhaps contained in the subsoil, in which they may have become deficient. This essential presence of the earths in the commonly cultivated crops, is much more considerable in amount than is commonly imagined, as will be under-

stood by the result of an analysis of two pounds of each of the following seeds, and of rye straw, the products of earths and metallic oxides from each being given in grains.* From this little table the farmer will not fail to observe, how extensively the earths are absorbed by his crops, and how steadily they are carried away from his lands by all cultivated vegetables :—

	Wheat.	Rye.	Barley.	Oats.	RyeStraw.
Silica	13.2	15.6	66.7	144.2	152.0
Carbonate of lime (chalk)	12.6	13.4	24.8	33.75	46.2
Carbonate of magnesia	13.4	14.2	25.3	33.9	28.2
Alumina (clay) . .	0.6	1.4	4.2	4.5	3.2
Oxide of maganese .	5.0	3.2	6.7	6.95	6.8
Oxide of iron . .	2.5	0.9	3.8	4.5	2.4†

These facts cannot be too carefully considered by the agriculturist, for he will remember that whatever powers, real or imaginary, a plant may possess of absorbing and decomposing water, the gases of the atmosphere, or those evolved during putrefaction, so as to form purely vegetable substances, yet the most profound philosophers have never concluded that they possess the magic property, by such combinations, of forming the earths, alkalies, and metallic oxides, which are as invariably and as essentially the constituents of plants, as the carbon, the hydrogen, and the oxygen which abound

* Schraeder Gehlen's Journ. vol. iii. p. 525.

† It is from these causes that corn exporting countries are gradually impoverished by the long-continued drain of their organic and earthy substances which are carried away in its corn; thus Sicily, once the most fertile of the Roman possessions—the granary of the Mediterranean—is now poor and unproductive.

throughout the vegetable world. The first great class may, and most certainly are, absorbed from the atmosphere, and from water, and formed into new combinations by some mystic process of the plant, but the earths can only be absorbed from the soil.*

The chemical effect of pulverizing and breaking up a subsoil, is certainly advantageous to the plant in two ways, besides others with which we are very likely at present unacquainted; first, it renders the soil penetrable to a much greater depth by the roots, or minute fibres of the plant, and consequently renders more available any decomposing matters, or earthy ingredients, which that substratum may contain; and secondly, it renders the soil much more freely permeable by the atmosphere, rendering, in consequence, a greatly increased supply, not only of oxygen gas to the roots of the plants, but also yielding more moisture, not only from the soil, but from the atmospheric air, which moisture, let it be remembered by the cultivator, is in all weathers as incessantly absorbing by the soil as it is universally contained in the atmosphere, abounding most in the latter, in the very periods when it is most needed by the plants—that is, in the warmest and driest weather.† This property possessed by the soil of *ab-*

* At the Lytham meeting in October 1839, where speaking of heavy “tight bound soils,” Mr. Fair observed that “by applying moss, and a calcareous substance to such stubborn soils, you introduced a loosening operation, and very materially improved the quality of the land.” For the soil to which he alluded no process of cultivation would be better.—*Brit. Farm. Mag.* vol. 3. p. 460.

† The *extremities* of the roots too, are thus farther removed from the scorching influence of the sun’s rays.

sorbing moisture from the atmosphere, and the importance of increasing that power by pulverizing the soil, is not nearly so well understood as is desirable, although the farmer has the means of convincing himself of the fact by the most simple experiments. It is, in truth, an almost unfailing test of the comparative value of soils, as was long since observed by Sir H. Davy, a conclusion in which I have often had occasion to agree.

“The power of the soil,” says this great chemist, “to absorb water by cohesive attraction, depends, in a great measure, upon the state of division of its parts; the more divided they are, the greater is their absorbent power. The power of soils to absorb moisture from air, is much connected with fertility; when this power is great, the plant is supplied with moisture in dry seasons; and the effect of evaporation in the day, is counteracted by the absorption of aqueous vapour from the atmosphere by the interior parts of the soil during the day, and by both the exterior and interior during the night. The stiff clays, approaching to pipe-clays in their nature, which take up the greatest quantity of water, when it is poured upon them in a fluid form, are not the soils which absorb most moisture from the atmosphere in dry weather; they cake, and present only a small surface to the air, and the vegetation on them is generally burnt up almost as readily as on sands. The soils that are most efficient in supplying the plant with water by atmospheric absorption, are those in which there is a due mixture of sand, *finely divided* clay, and

carbonate of lime, with some animal or vegetable matter, and which are so loose and light, as to be freely permeable to the atmosphere. With respect to this quality, carbonate of lime and animal and vegetable matter are of great use in soils ; they give absorbent power to the soil, without giving it likewise tenacity ; sand, which also destroys tenacity, on the contrary, gives it little absorbent power. I have compared the absorbent powers of many soils with respect to atmospheric moisture, and I have always found it greatest in the most fertile soils, so that it affords one method of judging of the productiveness of land. 1000 parts of a celebrated soil from Ormiston, East Lothian, which contained more than half its weight of finely divided matter, of which eleven parts were carbonate of lime, and nine parts of vegetable matter, when dried at a temperature of 212° , gained in an hour by exposure to air saturated with moisture at a temperature of 62° , eighteen parts. 1000 parts of a very fertile soil from the banks of the river Parret, in Somersetshire, under the same circumstances, gained sixteen parts. 1000 parts of a soil from Mersea, in Essex, worth 45s. per acre, gained thirteen parts. 1000 parts of a fine sand from Essex, worth 28s. an acre, gained eleven parts. 1000 of a coarse sand, worth 15s. per acre, gained only eight parts. 1000 of the soil of Bagshot Heath gained only three parts.”*

And this absorbent power of atmospheric moisture is not only an inherent property in all fertile soils, and

* Lectures, p. 182.

a property which is increased with their depth, and by their pulverization,* but it exists in a still more remarkable degree in the commonly employed manures of the cultivator, and that, too, nearly proportionate to their usually assigned value. The following are the results of my own experiments :†—" 1000 parts of horse-dung, dried at a temperature of 100°, absorbed, by exposure for three hours to air saturated with moisture at 62°, 145 parts. 1000 parts of cow-dung, under the same circumstances, absorbed 130 parts. 1000 parts of pig-dung absorbed 120 parts. 1000 parts of sheep-dung absorbed 81 parts. 1000 parts of pigeons' dung absorbed 50 parts. 1000 parts of a rich soil, worth two guineas per acre, absorbed 15 parts.

This attractive power of the earths, and of manure, for the moisture of the atmosphere, is one of the most important facts to be kept in mind by the farmer,

* Mr. Viall, at the South Suffolk Meeting of 1839, when speaking of the subsoil plough, said, "I used it on a piece of light land for turnips—I ploughed it with the common plough five or six inches, and then with the sub-soil plough ten or twelve inches, and after I did so, it was no farther trouble to plough the land. When I began subsoiling first, I did three roods a day, with four horses and two men; this spring I did an acre. One subsoil ploughing is worth four others—it is afterwards like striking the plough over a feather bed. I then sowed it with barley; the crop was good, and it never faded away. It was a hot piece of land, and in dry weather some of it would burn, but after using the sub-soil it *did not*." He had also used it successfully on heavy clay land.—*Brit. Farm. Mag.*, vol. iii. p. 361.

† Essay on Salt, p. 19.

when he is considering the pulverizing and deepening his soils. It is also a property which all plants possess in a certain measure, but some in such a perfect degree, as to depend entirely upon it for all the moisture they need. Thus, the Aërial Epidendron, (*Epidendron flos aëris*), is often employed by the natives of the east, on account of the elegance of its leaves and flowers, and the exquisite odour which it diffuses, as an ornament, suspended by a silken cord from the ceilings of their rooms, where from year to year it continues to vegetate, putting forth new leaves, new blossoms, a new fragrance, entirely supported by the moisture and gases of the surrounding atmosphere. Many of the native plants of the east, nearly support themselves in the same way; some of the mosses of this country almost do the same.

The quantity of water consumed by plants, when in a state of healthy vegetation, is in fact so great, that, if it was not for the gentle steady supply, thus imperceptibly furnished to the soil by the atmosphere, vegetation would speedily cease, or only be supported by incessant rains. Thus, Dr. Hales ascertained, that a cabbage transmits into the atmosphere, by insensible vapour, about half its weight of water daily; and that a sunflower, three feet in height, transpired in the same period, nearly two pounds weight.* Dr. Woodward found that a sprig of mint, weighing 27 grains, in seventy-seven days emitted 2543 grains of water. A sprig of spearmint, weighing 27 grains, emitted in

* Vegetable Statics, i. 5, 15.

the same time 2558 grains ; a sprig of common nightshade, weighing 49 grains, evolved 3708 grains ; and a lathyrus of 98 grains, emitted 2501.*

It has been shewn by the experiments of M. Sausure with some sprigs of peppermint, that, when supplied with pure water only, and allowed to vegetate for some time in the light, that they nearly doubled the portion of carbon they originally contained. † This they could have procured only from the atmosphere ; and, under these circumstances, there is now little doubt of the correctness of the conclusion of M. Berthollet, that plants, by means of their leaves, have the power of decomposing the water, as well as the carbonic acid of the atmosphere, and furnishing with these elements, new combinations. How essential a free access of the atmosphere is to the roots of plants,

* Phil. Trans. 1699, p. 193.—“The power of soils to absorb moisture,” says Davy, “ought to be much greater in warm or dry countries, than in cold and moist ones; and the quantity of clay, or vegetable, or animal matter greater. Soils also on declivities, ought to be more absorbent than in plains, or in the bottoms of valleys. Their productiveness, likewise, is influenced by the nature of the subsoil, or the stratum on which they rest. When soils are immediately situated upon a bed of rock or stone, they are much sooner rendered dry by evaporation, than where the subsoil is of clay or marl; and a prime cause of the great fertility of land in the moist climate of Ireland, is the proximity of the rocky strata to the soil. A clayey subsoil will sometimes be of material advantage to a sandy soil; and in this case, it will retain moisture in such a manner, as to be capable of supplying that lost by the earth above, in consequence of evaporation, or the consumption of plants.”—*Lectures*, p. 186.

† *Recherches sur la Veget.* 51.

was long since shewn by M. Saussure, who found that oxygen gas is absorbed by the roots of plants, as well as by their leaves; and that it is at the roots united with carbon, and transmitted to the leaves to be decomposed. Even the branches absorb oxygen: in its absence, flowers will not even expand. † The advantages of a free access of oxygen to the roots of plants, has been still further shewn experimentally; it has been proved, that their vegetation is greatly encreased by nourishing them with water impregnated with oxygen gas; hence, too, the superiority of rain-water. Some remarkable experiments were made by Mr. Hill, demonstrative of the great benefit plants derive from oxygen gas being applied to their roots. Hyacinths, melons, Indian corn, &c., were the subject of the experiments. The first were greatly improved in beauty, the second in flavour, the last in size, and all in vigour. This is another use of a free access of atmospheric moisture; for M. Humboldt has clearly shewn, that a dry soil is quite incapable of absorbing oxygen gas. Now, it must be evident, even to the most listless observer, that the more deeply and finely a soil is pulverized, and rendered permeable, the greater will be the absorption of both oxygen and watery vapour from the surrounding atmosphere.

It is, perhaps, needless to prove, that the roots of commonly cultivated plants will penetrate, under favourable circumstances, much greater depths into the soil, in search of moisture, than they can from the

* Thomson:

resistance of the case-hardened subsoil, commonly attain. Thus the roots of the wheat-plant in loose deep soils, have been found to descend to a depth of two or three feet, or even more; and it is evident, that if plants are principally sustained in dry weather by the atmospheric aqueous vapour absorbed by the soil, that then that supply of water must be necessarily increased, by enabling the atmospheric vapour and gases, as well as the roots of plants, to attain to a greater depth; for the interior of a well pulverized soil, be it remembered, continues steadily to absorb this essential food of vegetables, even when the surface of the earth is drying in the sun.

And by facilitating the admission of air to the soil, another advantage is obtained,—that of increasing its temperature. The earths are naturally bad conductors of heat, especially downwards; thus it is well known, that, at the siege of Gibraltar, the red-hot balls employed by the garrison were readily carried from the funarces to the batteries in wooden barrows, whose bottoms were merely covered with earth. Davy proved the superior rapidity with which a loose black soil was heated compared with a chalky soil, by placing equal portions of each in the sunshine;—the first was heated in an hour from 65° to 88° , while the chalk was only heated to 69° .* This trial, however, must not be regarded as absolutely conclusive, since the surface of the black soils naturally increases more rapidly in temperature when exposed to the direct rays of the sun,

* Elements of Agr. Chem. 178.

than those of a lighter colour. A free access of air to all soils also adds to their fertility, by promoting the decomposition of the excretory matters of plants, which otherwise would remain for a longer period, to the annoyance of plants of the same species.

To the truth of these conclusions and laborious experimental researches of the chemist, does not the practical testimony of the ablest cultivators of all countries and in all ages concur? Thus, in enforcing the advantages of rendering the soil more completely permeable by the atmosphere, nearly two thousand years since M. P. Cato asked the Italian farmers, "What is good tillage? To plough. What is the second? To plough. The third is to manure." Cato, however, mistook the cause of the benefit, for he says, "He who stirs his olive-ground oftenest and deepest, will plough up the very slender roots; if he ploughs ill, the roots will become thicker, and the strength of the olive will go to the root."* Virgil, when giving an erroneous explanation of the advantages of paring and burning, says, "The heat opens more ways and hidden vents for the air, through which the dews penetrate to the embryo plants."†

Do not, at this very period, Lord Leicester and all the best of England's agriculturists, find the greatest advantage from stirring the ground between their rows of drilled turnips, for the sole purpose of promoting the access of the air to their roots? And that, too, on soils where a weed is hardly to be seen? Is not one

* Lib. 61.

† Geor. i. 90, 91.

great object of fallowing to produce, by pulverizing and deepening the soil, the same result? Did not Jethro Tull labour long, and sometimes too sanguinely, in illustrating the same position? And does he not support the subsoilers' conclusions when he says,—

“I have had the experience of a multitude of instances, which confirms it so far, that I am in no doubt that any soil (be it rich or poor) can ever be made too fine by tillage. For it is without dispute, that one cubical foot of this minute powder may have more internal superficies than a thousand cubical feet of the same or any other earth tilled in the common manner; and I believe no two arable earths in the world do exceed one another in their natural richness twenty times; that is, one cubical foot of the richest is not able to produce an equal quantity of vegetables, *cæteris paribus*, to twenty cubical feet of the poorest; therefore it is not strange that the poorest, when, by pulverizing, it has obtained one hundred times the internal superficies of the rich untilled land, should exceed it in fertility; or, if a foot of the poorest was made to have twenty times the superficies of a foot of such rich land, the poorest might produce an equal quantity of vegetables with the rich. Besides, there is another extraordinary advantage when a soil has a larger internal superficies in a very little compass; for then the roots of plants in it are better supplied with nourishment, being nearer to them on all sides within reach, than it can be when the soil is less fine, as in common tillage and the roots in the one must extend much farther

than in the other; to reach an equal quantity of nourishment, they must range, and fill, perhaps, above twenty times more space, to collect the same quantity of food. But in this fine soil, the most weak and tender roots have free passage to the utmost of their extent, and have also an easy, due, and equal pressure everywhere, as in water."*

And it is fortunately in our power to prove that a thorough subsoil-ploughing or trenching is a *permanent* improvement of the soil,—is productive of continued good results for a series of years after the operation has been performed. I have often had occasion to remark this in my own experience; and that how slowly ground which has been once disturbed acquires its original degree of solidity, every railroad contractor or builder can furnish satisfactory evidence. Neither are the good effects of this deep-soil cultivation merely dependent upon the effects of the manure being more deeply placed, or more widely diffused in the soil; the mere loosening and extended pulverization of any soil, is certain to render that soil more productive. It is seldom that any experiments can be carried on to any extent, which will prove this fact more conclusively than those made some years since by Mr. Withers and other planters in Norfolk, with their timber plantations, of which, nearly in his own words, the following is the detail. In the year 1811, five acres of poor black sandy land were planted in the parish of Holt. The land had been recently inclosed from the common, and was

* Tull on Tillage, 43.

covered with heath and whins. Scotch fir, and a proper assortment of deciduous trees, were planted in large holes. The fir succeeded pretty well, but the other trees made no progress ; and although, he adds, "I yearly filled up the vacancies occasioned by death and decay, I found, at the end of four or five years, that all the trees but the Scotch fir, with very few exceptions, were either dead, or in a dying state. I then had all the ground *trenched*, and all the vacancies filled up with oak, ash, chesnut, elm, and other trees, and I have kept it regularly hoed, and free from weeds ever since. The consequence has been, that the last-mentioned trees have made such a rapid growth, that I have been enabled to clear away the greater part of the fir, and the remainder must be taken out in a year or two, to give space for the other trees. One mountain-ash, which had escaped the deadly effect of the heath, whins (and iron-bound soil), gave a decided proof of the advantages of trenching and cleaning the land. This tree had barely kept alive, not making more than two or three inches of wood in a season ; but in the year following the trenching, it threw out two leading shoots, the smallest of which, when cut off at Michaelmas, measured six feet two inches." In the spring of 1819, another piece of ground, containing half an acre, adjoining the five-acre field, was planted with the same description of trees. "This land was trenched two feet deep, and has since been kept perfectly clean ; and so great is the advantage of preparing the land properly, in the first instance, that the trees in this piece

are now much superior to those planted eight years before, although the latter have had the benefit of hoeing for the last nine or ten years."*

Some plantations, made in the same years, adjoining those of Mr. Withers, and on the same kind of soil, which is more like that of Bagshot Heath than any other with which I am acquainted, entirely confirm the conclusions I have drawn from those of the former. Mr. Hardy's were planted in holes dug in the heath,—Mr. Gurney's land was previously ploughed; both were planted with a good assortment of forest trees: but, at the expiration of three years, Mr. Hardy, finding many of his trees dead, and the others making little or no progress, trenched the land, and filled up the vacancies, and has since kept it regularly hoed, and free from weeds;—his neighbour's land has been entirely neglected, and the heath and whins suffered to grow to the height of several feet; the consequences are, that while in the one (which is divided from the other only by the road) there is a fine valuable plantation; in the adjoining all the deciduous trees are dead, and nothing remains but Scotch and larch firs. Another experiment of Mr. Withers, begun in 1823, on fifteen acres of the same land, is not so decidedly applicable to my argument, because he there employed a quantity of manure; yet it still affords a very valuable practical illustration of the advantages of pulverizing and sub-soil-ploughing.

"I caused," he says, "the land to be double-plough-

* Memoir on Forest Trees, p. 7.

ed, first with two horses, and then with four, following in the same furrow, by which means the soil was stirred to the depth of eighteen to twenty inches. I fortunately found the remains of an old marl pit in the field, from which I barrowed and spread twenty cart loads per acre. This I suffered to lie and pulverize all winter; and in the following April (1824) I spread twenty loads per acre of good rotten dung, ploughed it in, and planted the land with oak, ash, elm, chestnut, and black Italian poplar plants. They took exceedingly well, and many of them made vigorous shoots the first summer; the second year they nearly covered the ground; but during the next summer their growth was prodigious, many of the trees making shoots upwards of five feet long, and, upon an average, increased that year full three feet in height. The severe drought which has burnt up trees on land in a foul and poor state, has had the effect of adding considerably to the growth of these. *They have never had the appearance of wanting moisture*, although not a drop of rain fell upon them for a period of several weeks during the very hottest part of the summer of 1826. This luxuriant growth I attribute to the deep ploughing,—to the highly manured state of the land, and to its being constantly kept clean *and loose upon the surface*, by means of the hoe; and I firmly believe, that, when land is in this state, the weather in England can never be too hot for forest trees.” *

The experience of the great Scotch planters confirms

* Memoir, p. 19.

all that is here advanced. Thus Sir Walter Scott—no inconsiderable planter,—tells us, when speaking of manuring and fallowing the soil intended for plantations : —“ Every plantation which the proprietor desires to see rush up with unusual rapidity, ought to be prepared by one of these methods ; or, which is best of all, by deep trenching with the spade.”* Scott, however, thought that the advantage of trenching woodlands ceased in ten or twelve years. “ At a certain period the fibres reach the subsoil, which the spade or plough has not disturbed, and thus the final growth of the tree which has enjoyed this advantage, is often not greater than that of its neighbour, upon which no such indulgences were ever bestowed.”

Granting that these conclusions of Sir Walter Scott were, in some instances, correct, yet still he has assigned to one cause effects which are more certainly attributable to another. In ten or twelve years the ploughed soil will, if undisturbed, gradually become very nearly, if not quite, as close, as case-hardened, and as little permeable by the atmosphere as any of the unploughed soils. It will then be nearly equally ill supplied with moisture, by absorption, as that which has rested totally untilld. I am able, too, to add the testimony of Sir Henry Steuart to the truths I am endeavouring to illustrate.

“ Trees,” says this great planter, “ more than agricultural crops, require depth of soil to raise them to perfection ; . . . and as it appears plain, that,

* Quarterly Review for 1829.

both in the north and in the south, the size of the wood will be mainly attributable to the depth of the soil on which it grows, it should be the chief object of the planter to promote that capital object. . . . Deepening can only be executed with effect by trenching or double digging (for the plough can do little in such a business); and pulverizing is naturally combined with that process. . . . Pulverization, or the mechanical division of parts, is applicable to all soils in proportion to their adhesive texture, as even the most siliceous, if not duly stirred, will become too compact and dense for the admission of air, rain, and heat, and, by consequence, for the free growth of plants. . . . Strong upland clays, not submitted to the plough or the spade, will, in a few years, be found in the possession of fibrous-rooted perennial grasses, which form a clothing on their surface, or of strong tap-rooted trees, such as the oak, which force their way through the interior of the mass. For these reasons, the first and great object should be to give scope to the young roots and fibres, because, without fibres in abundance, no woody plant can shoot freely and develop its parts, whatever be the richness of the soil. . . . Manure is ineffectual towards vegetation until it becomes soluble in water; and it would remain useless in a state of solution if it so abounded as to exclude air, for, in that case, the fibres or mouths of plants would be unable to perform their functions, and they would soon drop off by decay. . . . Let it be observed, also, that an open soil, besides being

favourable to the transmission of nutriment to the roots of plants, is likewise favourable to their extension, and thereby enlarges the field, whereby nutriment is derived. Nor are these the only benefits resulting from a friable soil; for, in addition to its being the best adapted to supply vegetables with food, it is always most suitable for effecting those changes in the *manure* itself which are equally necessary to the preparation of such food; and animal and vegetable substances, exposed to the alternate action of heat, moisture, light, and air, undergo spontaneous decompositions, which, independently of it, would not take place. . . . Soils are surprisingly benefited by aëration, and the free admission of the weather into their interior parts. This is generally considered as the principal use of fallowing, and its importance in gardening is proved by summer and winter edging up. “Had Tull,” adds Sir Henry Steuart, (in all of which I cheerfully concur,) “who flourished about a century ago, been acquainted with chemistry as at present improved, he would not have missed that permanent fame to which his ingenuity so well entitled him. He was unquestionably the first practical advocate for the power of pulverization, but he was deceived by its astonishing and various effects, without being able to perceive its limits. Hence, he was led into the erroneous belief, that pulverization could even supply the place of manures in farm management.” *

I have quoted the experimental researches of these

* Planter's Guide, 464.

scientific planters at considerable length, because their examinations were confined to crops which were to be advancing to maturity for a series of years. Both the trenching and the hole-planting, when once completed, were to remain undisturbed and unmanured for a lengthened period. If, then, there was any advantage in subsoil-ploughing, or in pulverizing the soil, the trees growing upon it would certainly sooner or later betray the fact. And both Sir H. Stewart and Mr. Withers concur in proving that they did so. The results of the latter gentleman's system of planting I have witnessed; and I have, on a very small scale, experienced the same advantages of trenching in my own garden and plantations.

With regard to field crops, the testimony in favour of subsoiling the same kind of light sandy soil is equally important and unanswerable. Thus, Sir Edward Stracey, the inventor of the Rackheath subsoil-plough, says, "I have broken up nearly 500 acres of heath land with the plough. My crops have been nearly doubled. The wheat produced on the land so broken up has been fine plump grain, weighing about 63½ lb. to the imperial bushel, has produced the best price in the market, where, before the deep ploughing, the same land scarcely produced the seed. The wheat was so poor and shrivelled, that nobody would look at it; and, as I had no manure to lay upon the ground, I can ascribe the goodness of the crop to nothing but the deep ploughing." *

* Brit. Farm. Mag. vol. i. p. 235.

In a very recent communication to the Secretary of the English Agricultural Society, Sir E. Stracey has given some of the results of his experience with the Rackheath Subsoil Plough, at some length, and they are of a description which cannot be too generally known :—

“On my coming,” he remarks, “to reside on my estate at Rackheath, about six years since, I found 500 acres of heathland, composing two farms, (which had been enclosed under an Act of Parliament about 40 years,) without tenants; the gorse, heather, and fern shooting up in all parts. In short, the land was in such a condition, that the crops returned not the seed sown. The soil was a loose loamy soil, and had been broken up by the plough to a depth not exceeding *four inches*, beneath which was a substratum, (provincially called an iron pan,) so hard, that with difficulty could a pick-axe be made to enter in many places; and my bailiff, who had looked after the lands for 35 years, told me that the lands were not worth cultivation—that all the neighbouring farmers said the same thing—and that there was but one thing to be done; viz., to plant with fir and forest trees; but to this I paid but little attention, as I had the year preceding allotted some parcels of ground, taken out of the adjoining lands, to some cottagers; to each cottage, about one-third of an acre. The crops on all these allotments looked fine, healthy, and good, producing excellent wheat, carrots, peas, cabbages, potatoes, and other vegetables in abundance. The question then was, how was this

done? On the outside of the cottage allotments, all was barren. It could not be by the manure that had been laid on, for the cottages had none but that which they had scraped from the roads. The magic of all this I could ascribe to nothing else but the spade; they had broken up the land 18 inches deep. As to digging up 500 acres with the spade, to the depth of 18 inches, at an expense of 6*l.* an acre, I would not attempt it. I accordingly considered, that a plough might be constructed so as to loosen the soil to the depth of 18 inches, keeping the best soil to the depth of 4 inches, and near the surface, thus admitting air and moisture to the roots of the plants, and enabling them to extend their spongioles in search of food—for air, moisture, and extent of pasture, are as necessary to the thriving and increase of vegetables, as of animals. In this attempt I succeeded, as the result will shew. I have now broken up all these 500 acres, 18 inches deep; the process was by sending a common plough, drawn by two horses, to precede, which turned over the ground to the depth of 4 inches; my subsoil plough immediately followed in the furrow made, drawn by four horses, stirring and breaking the soil 12 or 14 inches deeper, but not turning it over. Sometimes the iron pan was so hard, that the horses were set fast, and it became necessary to use the pick-axe to release them before they could proceed. After the first year, the land produced double the former crops, many of the carrots being 16 inches in length, and of a proportionate thickness. This amendment could

have arisen solely from the deep ploughing. Manure I had scarcely any, the land not producing then stover sufficient to keep any stock worth mentioning, and it was not possible to procure sufficient quantity from the town. The plough tore up by the roots all the old gorse, heather, and fern, so that the land lost all the distinctive character of heath land, the first year after the deep ploughing; which it had retained, notwithstanding the ploughing with the common-ploughs, for 35 years. Immediately after this subsoil-ploughing, the crop of wheat was strong and long in the straw, and the grain close-bosomed and heavy, weighing full 64lbs. to the bushel. The quantity, as might be expected, not large, (about 26 bushels to the acre,) but great in comparison to what it produced before. The millers were desirous of purchasing it, and could scarcely believe it was grown upon the heath land, as in former years my bailiff could with difficulty get a miller to look at his sample. Let this be borne in mind, that this land then had had no manure for years, was run out, and could only have been meliorated by the admission of air and moisture, by the deep ploughing. This year the wheat on this land has looked most promising; the ears large and heavy, the straw long; and I expect the produce will be from 34 to 36 bushels an acre: the wheat, the "golden drop." My Swedish turnips on this land this year are very good; my pudding and sugar-loaf turnips failing in many parts, sharing the fate of those of my neighbours, having been greatly injured by the torrents of rain.

which fell after they had shown themselves above the ground. Turnips must have a deep and well-pulverised soil, in order to enable them to swell, and the tap-roots to penetrate in search of food. The tap-root of a Swedish turnip has been known to penetrate 39 inches into the ground. I will not detain my readers much longer, and will only add two or three general observations.

“1st. The work done by the plough far exceeds trenching with the spade, as the plough only breaks and loosens the land all around without turning the subsoil to the top, which in some cases (where the subsoil is bad) would be injurious to the early and tender plant; and if the subsoil is good, it would be rendered more fit for vegetation after the air and moisture had been permitted to enter. The ploughing is also far preferable to trenching by the spade even for planting, as it may be done at one-fourth the expence.

“2ndly. It were very preferable, if possible, to work the horses abreast, pair and pair; but, in using this plough, the horses *must* work in a line, for if abreast, the horse on the land ploughed would soon be fatigued by sinking up to his hocks: and, to render the draught more easy, the second horse from the plough should not be fastened to the chains of the horse next the plough; but the chains of that second horse should be made long enough to be hooked about 2 feet behind the back-band of the chains of the horse next the plough, so that the second horse will draw at an angle

of about 33 degrees ; otherwise, were the chains of the second horse hooked in front of the back chain, he would pull the whole weight of his draught, together with that of the horses preceding him, on the back of the horse next the plough ; and the strength of that horse would be lost in the draught, as his whole powers would be exerted in his endeavours to prevent being brought down upon his knees. By so arranging the chains, the power of 3 horses would be equal to that of 4.*

“ Now, being on the subject of the subsoil-plough, I may as well tell you I have contrived another plough, from the use of which the greatest benefit has been

* In the same volume of the English Agricultural Society's Journal, will be found an excellent paper, by the Rev. W. L. Rham, on subsoiling clay lands, with and without under-draining; and there is also a letter by Mr. Richard White, of Oakley Park, in which he alludes to the disadvantages arising from the ordinary mode of working the subsoil plough, and their remedy. He says, “ I first commenced with swingle trees and eight horses, from which I found great difficulty, from the leading horses causing great pressure on the backs of the foot horses. After this trial the Tumbrel wheels were resorted to, which did better, but were not satisfactory, as this method caused one set of horses to walk upon the ploughed land. It then struck me, that double shafts, with low wheels, would obviate all these difficulties. I have now adopted this method. Six horses are invariably used. I estimate the expense of each horse at 3s.6d. per day, each, and that these plough one acre per day, so that one guinea per acre is added to the expense of draining, getting stone, &c. The land subsoiled is not trod upon by any of the horses; and only one of the horses of the pair, in the plough that precedes the subsoil plough, walks in the furrow. This method appears to be generally approved of by those persons who have seen it work.”—*Eng. Ag. Soc. Journ.* vi. p. 248.

derived by my park land. I call this my 'sub-turf plough.' It is used to loosen the turf about $10\frac{1}{2}$ inches deep below the surface, without turning over the flag; loosening the soil underneath—consequently, admitting the air and the rain—and permitting the roots of the herbage to spread in search of food. There are no marks left by which it can be known that the land has been so ploughed, except from the straight lines of the coulter, at the distance of about 14 inches one from another. In about 3 months from the time of ploughing, these lines are totally obliterated, and the quantity of aftermarth, and the thickness of the bottom, have been the subject of admiration of all my neighbours. Another advantage from this sub-turf ploughing is, that before that took place, water was lying stagnant in many parts (after heavy rains), especially in the lower grounds, to a great depth: now, no water is to be seen lying on any part, the whole being absorbed by the earth."†

* Journal of Eng. Ag. Soc. v. 1. p. 253.

† By this sub-surf plough of Sir Edward Stracey's, will be opened a new sphere of usefulness for the subsoiling system; for it will enable the grazier to improve, in a very great degree, the produce of pastures, which he is now, perhaps, restrained by the covenants of his lease, or other motives, from breaking up—even for a season. The object in using a plough of this kind should be, to disturb the sub-soil, under the turf, *as much and as deep as possible*, without breaking the turf to pieces. And yet the thorough agitation, and even partial breaking of the turf, will not be unattended with benefit to the grass. Its beneficial operation must be accounted for on the same principle as that of the subsoil plough, in rendering the soil more permeable to the gases and aqueous vapours of the atmosphere,

And for heavier soils, the evidence in favour of subsoil-ploughing is equally valuable. In the year 1838, an experiment was made by Sir James Graham, which is important in several respects. It was on a field of about eight acres, of the poorest and wettest land. "The surface-soil is about five inches deep of black earth, of a peaty quality. The subsoil is a weeping retentive clay, with sand and rusty gravel intermixed. This clay extends to the bottom of the drains, which are of tile, laid thirty inches deep in every furrow. This field was rented by the out-going tenant at 4s. 6d. per acre. It was in pasture of the coarsest description, overrun with rushes and other aquatic plants. After draining on one-half of this field, I used Mr. Smith's subsoil plough. On the other half I trench-ploughed to the depth of ten inches, by two ploughs following in succession. In the first part, not mixing with the surface any of the subsoil; in the last part, commingling the surface and the subsoil in nearly equal proportions. The whole field was heavily, but equally manured, and planted with potatoes; and though the potato crop, even on good land in this neighbourhood (Cumberland), was below an average, yet the crop in this field exceeded an average, and yielded about twelve tons per acre. The field is equally drained in every part. The crop was so equal throughout the

long, perhaps, excluded by the hard, stock-trodden surface of turf. The agriculturists of England will at once see the great advantages which must be derived by their grass lands from the use of this sub-turf plough.

field, that I am unable to pronounce positively which part was the best, but I am inclined to give the preference to that portion where Mr. Smith's subsoil-plough was used." *

In a letter to the Secretary of the English Agricultural Society, dated in January 1840, Sir James Graham adds—In a communication which I addressed to you in January last, I mentioned a field of 8 acres of poor and wet land, underdrained with tiles, one-half of which I had trench-ploughed to the depth of 10 inches, by two ploughs following in succession; the other half of which I ploughed with Mr. Smith's subsoil-plough, following a common plough, to the depth of 15 inches. In every other respect this field received the same management throughout. I stated that the crop of potatoes yielded 12 tons per acre, and was nearly equal in both parts of the field; but that, in the course of winter, the part where Mr. Smith's plough had been used appeared to me to lie more dry, and to be more mellow. In spring this field was sown with oats and grass-seeds, by the tenant, under the superintendence of my agent. The quantity of seed sown per acre, and the general treatment of the whole field, were the same. The summer has been unusually wet; yet the crop was excellent, and the grass seeds are most promising. One quarter of an acre was accurately measured off on that part of the field where Mr. Smith's subsoil-plough had been used; the produce was thrashed separately by hand, and yielded 13

* Journal of the Eng. Ag. Soc. vol. i. p. 31.

imperial bushels; equal to 6 quarters 4 bushels to the statute acre. Another quarter of an acre was measured off on that portion of the field where trench ploughing had been used, and where the subsoil had been brought to the top. This quarter of an acre yielded 11 imperial bushels of oats; equal to 5 quarters 4 bushels to the statute acre. Thus the measure of the corn produced by the land where Mr. Smith's plough was used is one-sixth more than the produce of the land which was trench-ploughed. The oats are potatoe-oats, of superior quality, in both cases; but the weight of the imperial bushel from the subsoiled land is 3 stones, while the weight of the imperial bushel from the trenched land is 3 stones and 1 lb.; thus, the weight from the trenched land is greater per bushel, but by no means equal to countervail the deficiency of quantity.

“When it is remembered that the outlay on this land was 6*l.* 18*s.* 4*d.* per acre, and that 2 years ago, before it was drained, the rental was only 4*s.* 6*d.* per acre, it is clear that the value of this single crop not only repays the whole cost of the improvement, but is more than the fee-simple value of the land before it was improved. In addition to this experiment, I have had another year's experience of the effects of the subsoil-plough. I am confirmed in my opinion of its excellence; and the ploughmen, who at first were prejudiced against it, and condemned it as unwieldy, because it is a heavy and troublesome implement, now

readily admit its usefulness, and concur with me in preferring it to trenching.

“I am quite satisfied, that the use of the subsoil-plough is no less applicable to dry land, than to wet : on wet land, it encreases and ensures the operation of the drains ; but, on all land, by loosening the substratum, it adds to the effective depth of the soil, whereby the nourishment to the plant is augmented ; the root takes a deeper hold ; and a more genial temperature is equally maintained below the surface, throughout the year. If I mistake not, it will be found that sandy loams, no less than stiff clays, profit by this system of subsoil-ploughing : and that on dry land, no less than on wet, where sterility is the consequence of a hard, hide-bound, hungry subsoil, Mr. Smith’s treatment is correct, which breaks the crust without bringing it to the surface, until in time it has been mellowed by the natural effects of atmosphere and rain.

“In my former letter I mentioned a field of 20 acres of dry land, half of which I had ordered to be trench-ploughed to the depth of 14 inches, the other half to be stirred with Mr. Smith’s plough. This has been done; the whole field was equally manured with bone-dust, and sown with white globe turnips.

“I have since had a quarter of an acre of the turnips pulled, both on the land which was subsoiled and on the land which was trench-ploughed. The turnips have been carefully weighed, and the result is as follows :—

“ Weight of Turnips.

		Per Quarter-Acre			Per Acre.		
		Tons.	cwt.	qr.	Tons.	cwt.	qr.
“Quarter of an Acre of White Globe	}	4	19	1	19	17	0
Turnips, on land subsoiled . .							
“Quarter of an Acre of ditto, on	}	4	13	0	18	12	0
land Trenched-ploughed . .							
Difference in favour of Sub-	}	0	6	1	1	5	0
soiling over Trenching .							

“The land subsoiled, is certainly inferior to the land trench-ploughed; and I consider this experiment decisive against the prudence of bringing to the surface subsoil, even of the richest quality, before it has been mellowed by the process which Mr. Smith, of Deanston, recommends.” *

Such has been the effect of subsoiling on a retentive clay substratum. I am able to give, from the same Journal, an account of the result of the same operation on “a light sandy soil, from five to seven inches in depth, covering a stratum of hard gravel. This stratum varies in depth from eight to twelve inches; and below it there is a yellow sand, with a very slight admixture of loam.” The experiment, which was very successful, was made by the Speaker of the House of Commons, Mr. Shaw Lefevre, at Heckfield in Hampshire, in 1836, at an expense of 30s. per acre; and the effect upon the soil may be perceived, by contrasting its produce before and after the subsoil-ploughing.

* Jour. of English Ag. Soc., vol. 1, p. 245.

Year.	Produce per Acre.	Year.	Produce per Acre.
1833.	Turnips, not quite 2 tons.	1837.	8 tons.
1834.	Barley, not quite 4 sacks.	1838.	10 sacks.*

In the poor hungry black gravels of Spring Park, near Croydon, resting upon a substratum of sand, brought into cultivation by the talents of Mr. Hewitt Davis, the subsoil plough has been introduced with complete success; he has ploughed to a depth of 15 or 16 inches with 6 or 8 horses—he was first led to adopt this plan from noticing the very superior long-traceable luxuriance of his crops, growing on those spots in his fields where an under-drain had been formed, or an old tree removed; and he was so satisfied with the result on the gravelly, sandy-bottomed soils, that he has been induced with perfect success, to introduce it on several farms under his management.

Thus in 1838 he subsoiled a thin-skinned field of fourteen acres, resting on a bed of chalk, which cropped out so near the surface, that the lumps of chalk raised by the plough, when reduced to powder by the frost of 1838-9, actually made the field appear, at a distance, one perfect white sheet of chalk, which, as the land was on a steep bank, was visible for a considerable distance. Eight horses were here employed, and the plough reached to the depth of 16 or 18 inches. The land was neither manured or fallowed, had but one ploughing, yet it yielded in 1839, a crop of wheat

* Journal of the Eng. Ag. Soc. vol. i. p. 38.

which was full five quarters per acre. On deep clays his experience is equally in favour of subsoiling.*

It is always refreshing to find the observations of the farmer confirming the experiments of the chemist, as in those which have been made by the Hampshire farmers, who find, in the retentive soils of their stiff clay-formations, such as those in the north of that county, that when they are reduced, by dint of ploughing, to a fine mouldy state, so that the atmosphere can freely penetrate through them, that then the surface of the *subsoil* speedily becomes very moist, and continues so during the warmest weather. The more finely the soil is divided, the more steadily moist the surface of the substratum becomes. The farmers of the chalk-formation in the same county also have remarked, in the wheat crops growing on the edge of chalk-pits, that as the soil near the edge of the pit becomes thus loosened by the removal of the earth, that then the roots of the wheat-plants growing in the immediate neighbourhood of the pits, elongate themselves in a remarkable manner, some of them reaching to a depth of three or four feet, and this, too, in the same chalk of which the superstratum is principally composed. In this and similar instances, the extension of the roots of the plant in search of nourishment, is well

* Mr. Davis has authorised me to say that he will be happy to shew his farm, at Spring Park, near Croydon, which consists of the poorest cultivated soil he ever met with, to any agriculturist who will favour him with a call. He first used a subsoil plough of his own construction in 1832.

worthy of remark, as proving the efforts which a plant thus situated makes to acquire nourishment, which, in such instances, is most likely either moisture, or the gases of the atmosphere, since here we find, that the chemical composition of the substratum is very similar to that of the surface-soil. The required ingredient, therefore, could not be chalk or silica; and it is not likely that alumina was needed, from the small proportion in which it exists in plants. Decomposing organic matters must be nearly absent from the iron-bound substratum, so that atmospheric air and water were the only food of plants likely to be found by the roots of the wheat-plant in diving so deeply into the loosened chalk.*

Such, I think, are the reasonable advantages derivable from the subsoiling system, benefits which, on most soils, must be more or less easily within the reach of the cultivator. It possesses, too, the great advantage of improving the land from its own resources. No other district need be impoverished, no expensive artificial fertilizers

* "Mr. Johnson's suggestions," says the excellent editor of the *British Farmer's Magazine*, in a flattering notice of the portion of this work which appeared in the *Quarterly Journal of Agriculture*, "'On Increasing the Depth of Soils,' are well worth the attention of all farmers who wish (as what farmer does not?) to make the most of a meagre soil. We have ourselves, at the last harvest, proved the advantage of his theory, of breaking up a dry chalky understratum, for a crop of wheat, on a clover stubble; the part so broken up or subsoiled, having yielded from eight to ten bushels more per acre than the part ploughed only with a single furrow."—*Brit. Far. Mag. January*, 1840.

procured, to enable the farmer to render that portion of his land productive, which he may have hitherto neglected. He has only to avail himself of the advantages which the improved construction of agricultural machinery now offers for his service.

There are many situations, in which, from the small size of the enclosures, or the want of sufficient animal power for the easy working of the subsoil-plough, the cultivator may prefer the employment of manual labour; and it is fortunately found by experience, that the difference in the expense of deep digging, or spade husbandry, is not materially different from that of the subsoil plough. A great mass of information on this head, has been collected by Dr. Yelloly, not however so much with the view of showing the increased fertility of the soil by deep stirring, as with the intention of demonstrating the immense field which is thus opened for the profitable labour of a teeming and increasing population; and it was with this object, that when addressing the statistical section of the British Association at Liverpool, in 1837, he observed;—

“The trials which have been hitherto made of spade husbandry, in various parts of the kingdom, have been insufficient, in point of extent, to afford any adequate criterion of the general applicability of that practice. Such trials, indeed, have been usually regarded, either as matters of speculation and experiment, or as charitable efforts adopted by the benevolent to give employment to the poor, without reference to pecuniary expediency. I have, therefore, thought it might be

acceptable to the Association, to be informed of the results of a much more ample employment of that mode of cultivation, than has hitherto, as far as I know, been made in this country.

“The farm where the system is pursued, which forms the subject of this communication, is situated at Wattlefield, in the parish of Wymondham. It is the property and residence, and in the occupation of John Mitchell, Esq. The farm consists of 317 acres, of which 207 acres are arable, and 110 in pasture and plantations. It is a mixed soil, but is rather disposed to be heavy. The country is flat, and the land requires draining, which is effected by bushes and straw.

“As soon as it was known that Mr. Mitchell meant to adopt the spade culture extensively and permanently, and not merely as an experiment, or a temporary means of increasing employment, the early prejudices against it subsided; and as the labourers found that the remuneration was fully equal to that of piece work, and much more than the usual daily wages; and that every man, whether married or single, was paid according to the work done, it soon became very popular, and he was speedily able to command the services of the most steady and expert men in his neighbourhood. Though the process was begun with the spade, a strong three-pronged fork, of 14 inches deep, and $7\frac{1}{2}$ inches wide, which was found to be more manageable, and less expensive than the spade, was soon allowed to be substituted for it, on the application of the workmen. It cost 4s. 6d., instead of 6s. 6d.;

weighed 8lbs. ; and, when worked down, could be relaid at a trifling expense.

“The digging is effected by taking in about 4 inches of earth at a time, pressing perpendicularly, and getting to a proper depth at two thrusts. The earth is not, however, turned out of the trench to a greater depth than 10 inches, though the fork may get down as far as 13 or 14 ; but that which remains at the bottom, in the state of what is called “crumbs,” answers the purpose, equally with the earth which is thrown out, of forming a permeable medium for the roots of the plant which is to grow in it. The men prefer working together, in order that their labour may be as nearly as possible on the same description of soil ; but each takes in about 9 feet in width, so that his work can be easily measured. The plan is to have a breathing about every half hour ; and the men never work more than the regular amount of ten hours per day. Digging is, however, more laborious than the usual operations of agriculture, though it is much less so under the use of the fork, than the spade. They work the land in ridges of about 9 feet in width ; and the furrows dividing them are sometimes made by the plough, previously to the digging, and sometimes by the management of the labourers, during the work, assisted by the eye only.

“The men receive, for the ordinary digging after a white crop, from 2d. to 2½d. per rod of 30 square yards ; the price varying according to the tenacity

of the soil, and whether manure is to be dug in. * Where the land is to have a fallow crop, that is turnips, mangel wurtzel, or cabbages (for no part of the farm, or the land in the immediate neighbourhood, has ever a naked fallow), † there is first a ploughing, which is done at a season when the horses can be best spared, and afterwards a digging at from 1½d. to 2d. per rod. In preparing for a fallow crop, there is also an expense incurred in harrowing, and in raising a ridge with the plough, which last is worth about 7s. per acre.

“The men are paid the usual wages of the neighbourhood at harvest; but as the whole number ordinarily employed are not required at that period, those for whom there is no occasion, disperse themselves among the neighbouring farmers, with the understanding, that they may resume their employment when harvest is over, which they are always happy in doing.—Though digging is the principal occupation of

* This expense then, amounts to only £1. 13s. 4d. per acre; and in many situations, this digging to the depth of fourteen or sixteen inches, would be fully equal in effect to a summer-fallow, of several ploughings; on the mere score, therefore, of economy, the field-digging is, under certain circumstances, to be preferred.

† “Fallowing,” says Davy, “affords no new source of riches to the soil. It merely tends to produce an accumulation of decomposing matter; which in the common course of crops, would be employed as it is formed; and it is scarcely possible to imagine a single instance of a cultivated soil, which can be supposed to remain fallow for a year, with advantage to the farmer. The only cases where this practice is beneficial, seems to be in the destruction of weeds, and for cleansing foul soils.”—*Agr. Chem.* p. 23.

the men, yet they are employed in all the other common operations of husbandry, at the common rates of payment; and all the work on the farm is paid for, as much as possible, by the piece, except hay-making, which is paid for by the day. The ordinary earnings, in digging, are from 11s. to 12s. per week, according as the rate of wages may be high or low.*—Mr. Mitchell is of opinion, that a course of seven years, instead of the usual one of four years, is best adapted to spade husbandry; and his object has been, to act upon this system as much as possible. Being satisfied with the first trials, he soon augmented his farm to its present magnitude; and under the seven-years' course, the following would have been the descriptions and proportions of the various crops, had he been long enough a cultivator to carry his ideas into complete effect, namely:—

“1st year Fallow crop of turnips, cabbages, or beet		30 acres.
2nd ..	Barley.....	30 ..
3rd ..	} Clover, or artificial grasses.....	58 ..
4th ..		
5th ..	Oats.....	29 ..
6th ..	Beans, pease, or tares.....	30 ..
7th ..	Wheat.....	30 ..

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* It is the practice in Flanders not only to allow the surface that has been for 7 or 8 years employed in the production of various crops to rest, but to bring up another into action that has not merely had the advantage of repose, but the enrichment of a considerable portion of manure, which in a soil of a porous nature cannot fail to find its way below the usual depth of cultivation. Digging an acre of light

"It is to be observed, however, that he has always ploughed clover layer for the succeeding crop, not dug it; and that the horses, when not wanted for other purposes, are employed in assisting the diggers in preparing the land for the seed. Spade husbandry, indeed, can hardly be expected, even in its completest form, altogether to exclude the plough, when carried on to a considerable extent; for as a certain number of horses are necessary for various operations on a farm, these will naturally be employed in ploughing, when they are not required for other duty, rather than that they should stand idle. Twenty labourers, besides a bailiff, are kept upon the farm, instead of thirteen, who would be necessary under the ordinary system; and five or six horses, instead of twelve. With so small a number of horses, it is clear, that they would not be equal to all the demands of the hay and corn harvest; and hence, a good deal of the hay and corn are always stacked in the fields where they are grown.

"Mr. Mitchell considers it to be an advantageous consequence of spade cultivation, that it improves the soil so much, as to enable it to bear the clover or artificial grasses two years instead of one; by which means the expense of one year's tillage is saved in the

land, eighteen inches deep, in Flanders costs £1. 6s. 0d. Strong lands of the same depth £1. 11s. 2d.; and even when two feet deep only £2. 5s. 0d. With proper instruments and some experience, a labourer can dig an acre of light land eighteen inches deep in twenty-five days, and even two feet deep in thirty-five days.—*Sinclair's Code of Agriculture*, p. 391.

course adopted. Under this view of the subject, the four-course system is not so favourable to spade husbandry, as one of longer duration. He thinks it not improbable, likewise, that by the advancing amelioration of the soil, clover may be borne on it more than once in eight years, which is the shortest interval of its repetition in the county of Norfolk ; some of the other artificial grasses being substituted at the intervening period, for grass seeds. *

“Spade husbandry is not a system of expense or risk. Less capital is necessary for it than ordinary husbandry, in the smaller number of horses and implements required, while the advantages are speedily exhibited. Its tendency is to diminish and keep down the poor-rates, and to aid materially the favourable operation of the poor-laws ; while, at the same time, it raises the workman in the scale of society, by increasing the amount of his remuneration, and by making it dependent on steady habits of industry.

“It bears a considerable resemblance to horticulture in its operation on the soil, which it comminutes and cleanses much more thoroughly than can be done by the plough and harrow. By turning up the ground, likewise, five or six inches deeper than the plough, which does not ordinarily act on more than three or four inches of soil, there is an opportunity afforded for the descent and diffusion of the roots, which are

* Have the cultivators of these “clover-sick lands,” ever tried the effect of gypsum, at the rate of 2 cwt. per acre, spread on the young clover, on a wet April morning ?

often interrupted in their progress by a hard and impervious substratum; and in this way augmented means are allowed for their acquiring nourishment, through their spongioles, from the soil beneath. With regard to wheat, I have had an opportunity of observing, that the number and length of the roots are much more considerable in forked, than ploughed land.*

“It may, perhaps, be thought, that to lay down the plough, and employ in its stead the spade or fork, is to reject an important mechanical invention, and to take a step backward in human improvement. But it is not always that the highest power is the most convenient of application; and there are various examples, in which the more simple description of labour, may sometimes be advantageously substituted for the more complex. In agriculture, for example, the dibbling of wheat has very much superseded the broadcast and the drill, in several counties, owing to the saving of seed, which nearly, if not wholly, pays the difference of expense in broadcast; and the greater precision and aptitude of the operation in both cases, by means of which the produce is rendered both more certain and more considerable. The plough is indeed a clumsy and imperfect instrument, which the mecha-

* “This mode of improvement of waste lands is in the end the cheapest, because it is complete at once, and need not be repeated. In fields of ordinary difficulty indeed, two crops will repay the expense of trenching. In Aberdeenshire, not less than 20,000 acres have been added to its cultivated soil by this process.”—*Sinclair’s Code of Ag.*, p. 394.

nical philosopher has hardly thought it worth his while to aim at improving. It is quite inadequate to preparing the ground for various vegetable productions. Effective planting, whether of vines, forest trees, or shrubs, requires the soil to be not only dug, but trenched, in order to allow room for the roots to diffuse themselves in it. No gardener would think of planting potatoes, carrots or cabbages, in ploughed land, if he could get it dug; for the difference of produce far more than compensates the difference of expense. But if this were even not the case in agriculture, and the expense of digging land were no more than made up by the augmented produce, still an important balance would remain in its favour, in providing employment for the poor, at all times when there is a redundancy of labour beyond the usual and ordinary demand for it.

“In some other parts of Norfolk spade husbandry has been adopted to a small extent; and I had an opportunity, early last year, of witnessing a very auspicious commencement of the practice, on the part of Mr. Gedney, a very able and experienced agriculturist, at Redenhall, near Harleston, where he farms about 300 acres. Mr. Gedney’s trials were so encouraging, that he augmented his quantity of forked land, in the autumn of last year, from about 18, to 50 acres, on which he has grown very luxuriant, and perfectly satisfactory crops of wheat, barley, pease, beans, beet-root, turnips and potatoes. He did not meet with the same difficulty which Mr. Mitchell at first experienced, in

getting people to work efficiently at this new practice; and he pays from 1½d. to 2½d. per rod for digging to the depth of from seven or eight to twelve inches, though in almost all cases he prefers the greater depth. I am happy in finding, by a late communication from Mr. Gedney, that my own views as to the permanent improvement of the soil, by the continual elaboration of a considerable depth of its surface, are confirmed by that gentleman's observations on the same subject, though for a different reason—namely, from bringing a certain portion of the clay, where there is a clay bottom, into activity, by commixture with the ground above; and by loosening the substratum, and thus allowing a ready descent of the water to the drains and subsoil. Mr. Gedney also observes, that the pressure of the plough in moist weather, 'frequently glazes the bottom of the furrows,' and thus prevents the passing off of the water, the retention of which, 'in the mould which is intended for the reception of the seed, and on heavy soils, is too frequently succeeded by scanty crops, more especially when sown with barley.' Deep forking, he considers as peculiarly well adapted to barley after tares, by bringing up 'fresh soil,' which is 'very suitable for the young clover plants,' and thus tending 'to remove the prevailing complaint of the clover crop failing, when sown with barley after tares.' He agrees with Mr. Mitchell in the propriety of ploughing clover layer, instead of digging it; both because the expense would be greater than digging a broken soil, and because the solid flag, when merely turned over, is well

adapted to the germination of wheat, inserted into it by dibbling, and is unfavourable to the growth of black grass, with which heavy land is apt to be infested."*

The other mode of deepening and consequently permanently improving the fertility of a soil, is that of adding to the land a proportion of the earthy ingredient of which it is naturally deficient. It is true that, in many instances, the expense of the carriage of clay, or marl, or chalk, or sand, presents apparently an impediment to such an improvement—an obstacle, however, which very often will be found to arise from the cultivator not having taken into his consideration, first, the increased productiveness of the soil, by such an addition to its earths; and secondly the decrease in the after expenses of its cultivation; for the lands, whose earthy matters are mixed together in the most fertile proportion, are ever those which require the least labour in their cultivation, and the smallest supply of animal and vegetable manures to produce the most luxuriant effects.

* Dr. Yelloly on Spade Husbandry, pp. 3—13.—*Brit. Farm. Mag.* No. 4. N.S.—“The late Mr. Blakie objected, in trenching strong clays, to the customary process of turning over the top spit or the cultivated soil, and throwing the barren inert subsoil over it; but he recommends to turn the top spit on one side, and to shovel the crumbs of earth upon it. The subsoil in the bottom of the trench should then be dug without being raised, the top spit of the next trench placed upon it, the crumbs shovelled over it, and the ground carefully levelled as the work proceeds. In most parts of Biscay and the North of Spain, the fields are commonly cultivated by the spade—great crops of potatoes and turnips are raised by these means.”—*Sinclair*, 394; *Brit. Husbandry*, v. ii. p. 571.

On the poor soils, the farmer is compelled, by often-repeated expensive manurings with organic fertilizers, to promote that moisture-absorbing and retaining power of the soil, and to furnish to his crops that necessary supply of earthy constituents, which a better constituted soil affords to every crop, unaided. The farmer should, therefore, remember, when he is thus estimating the cost of the contemplated improvement, that his after-expenses of cultivation will not only be materially and permanently lessened, but his crops will in a similar manner be improved. It is evident, that considering the trifling original value of the earths which compose all fertile soils (clay, sand, and chalk), that it is the expense of moving them, which alone prevents their general admixture; and it is from feeling convinced of the great assistance which, in this respect, railways will, in many cases, afford the farmer, that I shall briefly notice the facilities which they, in common with all improved modes of conveyance, offer for their profitable admixture. In this course of proceeding, nature is again our guide; for the agriculturist will find, upon examining the composition of the best alluvial soils, that Providence has, in their formation, mixed together different strata, on a large scale, precisely as I have advocated in a minor way, for the cultivator's practice. Take for example the rich alluvial land of the lower portions of the valley of the Thames, which have been gradually formed in the course of ages, by the deposits brought down by the river from other lands. Nature has there mixed together the chalks of Berks and Ox-

ford, the clays of Surrey, and the sands of Kent and Middlesex, with the most admirable results; she has drawn together her elements from strata naturally barren, and by their admixture produced the richest of soils. The often-quoted first aphorism of Bacon, in his *Novum Organum*, here applies with the greatest force: "Man, who is the servant and interpreter of nature, can act, and understand no farther than he has, either in operation or contemplation, observed of the method and order of nature."

This interchange of soils, for the purpose of rendering them more fertile, has hitherto been retarded chiefly from the want of a sufficient means of reasonable conveyance; for, otherwise, the farmers of England are so generally aware of the advantages of the use of mineral fertilizers, that they have very generally availed themselves of every possible opportunity of profitably employing them.* Marl, which is a mixture

* "The best natural soils," said the illustrious Davy, "are those of which the materials have been derived from different strata; which have been minutely divided by air and water; and are intimately blended together; and in improving soils artificially, the farmer cannot do better than imitate the process of nature. The materials necessary for the purpose are seldom far distant: coarse sand is often found immediately on chalk, and beds of sand and gravel are common below clay. The labour of improving the texture or construction of the soil is repaid by a great permanent advantage; less manure is required, and its fertility insured; and capital laid out in this way, secures for ever the productiveness, and consequently, the value of the land."—*Elements of Ag. Chem.* p. 204.

of chalk and clay, or chalk and sand, was extensively used by our forefathers as a manure; and no one can read the account given by Pliny* of the agricultural operations of the early Britons, without being struck with the minute discrimination, the evident result of long attentive practice, which was displayed by them in the application of marl to particular soils; and from a very early period, the Cornish farmers have been used to employ, extensively, the sea sand of Padstow Harbour (which contains 64 per cent. of carbonate of lime), for the same purpose, carrying it from the sea shore; either in carts, or even on horses' backs, some miles up the country. This privilege they enjoy free from any toll to the proprietors of the shore, under a grant from Richard, Duke of Cornwall, confirmed by another of the 45th Henry III., in 1261, and supported by the statute 7th James I., c. 18, which declares this sand "to be very profitable for the bettering of land, and especially for the increase of corn and tillage, within the counties of Cornwall and Devon." This valuable employment of sea sand is, however, at present, of necessity, confined to the lands situated within a few miles of the sea-shore; and yet, according to Dr. Paris, fifty-four thousand single-horse cart loads of this calcareous sand, are annually consumed by the farmers in the neighbourhood of Padstow Harbour.

* Lib. xvii. 6, 7, 8.—There are old marl pits near Chichester, and in other parts of England, traditionally the work of the Romans, that have timber trees now in them that are evidently the growth of ages.

The farmers of Norfolk employ a similar description of sea-sand in the north-eastern part of that great agricultural county : and as, like the Padstow sand, it contains a considerable portion of carbonate of lime (chalk) it is found to be an immediate and permanent fertilizing addition to clay soils. It is, in fact, in the permanent increased value of the soil, by the use of mineral fertilizers, that their greater importance consists ; for the addition of chalk or clay, to the land, is not like the use of vegetable or animal manures, productive of benefit for one, two, or three, or four years only ; but the increased fertility of a soil by such a dressing is observable for twenty years, or even longer—for it improves its very staple.

Marl was certainly used by the early Italian cultivators, as a valuable addition to the soil of their fields. It is thus spoken of by Columella :—" If, nevertheless, you are provided with no kind of dung, it will be of great advantage to it to do, what I remember. Marcus Columella, my uncle, a most learned and diligent husbandman, was frequently wont to do ; viz. to throw chalk or marl upon such places as abound in gravel, and to lay gravel upon such as are chalky, and too dense and stiff ; and thus he not only raised great plenty of excellent corn, but made most beautiful vineyards ; for this same most skilful husbandman denied that dung ought to be applied to vines, because it would spoil the taste of the wine ; and thought that stuff gathered together out of thickets, and from among briars and thorns, or, in a word, any other sort of earth fetched from any

other place, and carried to them, was much better for making a plentiful vintage."*

The mixture of soils, we find from Theophrastus, was a practice common in his days : they found, it seems, the advantage of uniting the light with the heavy, the fat with the lean, and in fact, any that were of a contrary nature. This mixture, he tells us, not only supplies what shallow soils need in depth, but adds to the power of both ; so that a worn-out soil thus treated, begins again to bear crops, with renewed energy : thus barren clays, when thus fertilized, again become fruitful ; in truth, this mode of cultivation he deemed a complete substitute for manure. The inhabitants of Megara, besides practising this system, were used every fifth or sixth year to trench their land, digging as deep as they imagined the rain to penetrate, and bringing the under soil to the top ; for it was an axiom with the Megarean cultivators, that the lighter portions of earth proper for the nourishment of plants are always washed downwards as far as the influence of the surface water extends ; so that we see from this that the advantages of deep ploughing, or subsoiling, is not a very modern discovery.†

As the three earths, lime, alumina (clay), and silex (flint), constitute the principal ingredients in all cultivated soils,—the richest soils are those in which these

* Columella, book ii. c. 16. p. 93.

† Columella, lib. xi. c. 16. Theophrastus, lib. iii. c. 25.

three earths are mixed in the most fertile proportions ; the excess of any one of them renders the soil barren. The chalky lands of the south of England, contain by far too great a proportion of chalk (carbonate of lime) and flint ; they are deficient in clay, which, when added to them, is therefore a capital manure ; but this addition can only profitably be made by a very reasonable mode of transport. Yet the quantity of clay necessary for the purpose of fertilizing a sand or chalk soil, is seldom of any very great amount ; it is almost invariably required in such proportions as are within the means and expense of supply, furnished by a railway.

The farmer, however, must not suppose that what is commonly called clay is exclusively alumina, for such is not the fact ; some clay soil, analyzed by Sir H. Davy, taken from a field at Sheffield-place, in Sussex, contained about 28 per cent of alumina. Another from West Drayton 29 per cent. * Pottery clay contains only 33 per cent. of the same earth ; porcelain clay only 27 per cent ; the remainder being made up of water, silica, lime, and other matters. † The rich soils of the vale of Evesham, contain about 15 per cent. of alumina ; the sands of Holkham, brought into cultivation by the talents of Lord Leicester, less than one per cent : those of Bagshot Heath hardly a chemical trace. ‡

* Elem. of Agric. Chem. 176. † Thomson, vol. iv. p. 176.

‡ Davy, 175—202.

The soil of Bagshot Heath, near London, is composed, after being reduced to redness, of—

Coarse silicious sand	380
Fine silicious sand	9
Ferruginous clay and carbonate of lime	11
	<hr/>
	400

The expense of adding to such a sterile sand the requisite quantity of other earthy matters, is rarely so great as to render the attempt to improve it hopeless. At the suggestion of the present Archbishop of Dublin, an acre of shingle at Eastbourn, in Sussex, was covered with clay to the depth of three or four inches, at a cost of sixteen pounds: this has formed a plate to retain the mould, &c., which the tenant has added, who has hired this ground for fourteen years. So that, as is well remarked by the excellent proprietor of this soil, "no land is hopelessly barren." The deep clay soils of Sussex, the Weald of Kent, and many other parts of England, on the contrary, contain alumina in too great a proportion; they are, therefore, far too tenacious to be worked without considerable labour, retain the rain-water too long, and exclude the atmospheric air from penetrating to the roots of the plants growing upon them. The system of husbandry which their cultivators are obliged to adopt is, in consequence, both laborious and expensive. To such soils, the well-known fertilizing ingredients are chalk and sand; but here the expense of carriage alone prevents the farmer bringing his land

into a state of increased productiveness. He knows the nature of the impoverishing cause; he is fully aware of the remedy; but he wisely counts the cost—the distance is often too great for him to transport the manure.*

The poor drifting sands of Norfolk, Suffolk, and of Bagshot Heath, in the neighbourhood of London, offer us ready and melancholy instances of hundreds of thousands of acres of well situated land completely sterile, from the presence of an excess of sand; this earth, in some instances, constituting nineteen parts out of twenty of the soil. On such lands, the only vegetable products are the fern, the heath, and, occasionally, wretched plantations of Scotch firs. It is to such soils as these that the railroad offers invaluable advantages, by bringing to them the clay and chalk of other lands. These are the known fertilizers; but the expense of their carriage is usually, by the common roads, a complete prohibition to their use.

* On the heathy sands of Norfolk, much improvement might be effected by the application of marl. Mr. Kiddle, of Marsham, in that county, made many experiments with marl, which he preferred from long experience of the variety denominated "clayey marl," which he thought the best for sandy lands, even if brought from a considerable distance. *Com. Board of Ag.* vol. iv. p. 124. "A few years since," said General Vavasour, "I purchased, with other lands, a field of ten acres; it had been part of a common, inclosed about fifteen years before, and was tithe free, the soil sandy, mixed with moory earth. I ploughed and sowed it in divisions with various crops, most of which failed. Having discovered a stratum of rich clay marl, within four hundred yards of the field, I carted on 75 cubic yards per acre, at 10d. per yard, or £3 per acre." The result was, that the value of the land increased from 6s. to £1. 1s. per acre.—*Com. Board of Ag.* vol. iii. p. 520.

This mode of deepening and improving the soil, in spite of the drawbacks of heavy and expensive carriage, is even now much more extensive than might be reasonably anticipated ; thus many thousands of tons of chalk are annually shipped from the county of Kent, for the use of the Essex farmers, who readily pay three shillings a ton for it at the ports of Maldon, Colchester, or Manningtree, and then carry it as many as eight or ten miles into the country, for the use of their clay or gravelly soils, so that it costs them five or six shillings per ton before it is spread on the land. This large cost for carriage naturally renders the farmers fertile in economical expedients. They mix the chalk with earth, and then spread it on the land ; others add it to their dunghills ; and some are induced to save expense of carriage, by employing lime, and mixing it with earth. I have found, by actual experiment, that forty-one tons of lime contain as much earthy matter as one hundred tons of chalk. The saving of carriage, therefore, by preferring lime, is material ; but it is not always so desirable a fertilizer as chalk, and the first cost is very much greater. In those districts, however, where chalk is not to be had at a sufficiently reasonable rate, but limestone and fuel abound, the usefulness of the railway or other mode of conveyance, by the adoption of lime, is very materially extended. The same observations will, in a great measure, apply to the occasional transport of clay ashes instead of unburned clay ; since, by burning clay in clamps, its earthy fertilizing ingredients remain uninjured, while

its weight is reduced full one-half. In many situations, therefore, where fuel is reasonable, I am convinced that the carriage of the clay will be materially economized by previously drying or burning it. In some soils, however, the burning might not be advisable, since, by undergoing this process, its tenacity is materially lessened.

It is only necessary, in following a railway or canal in their line of country, to notice the different strata they cross in their course, to be convinced of the probable fertilizing advantages which might be derived by their judicious admixture. Take, for instance, the London and Birmingham Railway : after crossing the gravelly soils of Middlesex, to which chalk is an admirable fertilizer, it arrives in the neighbourhood of Watford upon the chalk formation of Hertfordshire, from whence an inexhaustible supply may be obtained. The railway continues on the chalk for some miles, and then, after passing over the gravel and chalk of Buckinghamshire, enters the stiff clays of Northamptonshire and Warwickshire, which are rich in alumina, for the improvement of the calcareous districts. These clay soils, on the other hand, are highly fertilized by the addition of chalk. Or, examine the course of the London and Southampton Railway ; follow it through the loams, gravels, clays, and heaths of Surrey and Hampshire, which chalk causes "to spring into life," until near Basingstoke it traverses the great southern chalk formation, extending to within a few miles of Southampton, when it again

enters the gravel. By its means, the heavy clays of Hants will be readily mixed with the chalk, and its chalk supplied to fertilize the gravel soils of which the New Forest presents so ready an example. In the case of the proposed Brighton and South-Eastern Railway, the same prospects are unfolded. There is the chalk formation, which extends from Brighton, for several miles in its course, whose soil is of the poorest description, from the nearly total absence of clay in its composition, which this railway could readily supply ; since after it leaves the chalk, it immediately enters upon a stiff clay formation. It then traverses a sand, and again crosses a clay district ; proceeds once more through sand, and terminates at its junction with the South-Eastern, in another very extensive chalk district.

Such a constant alternation of strata, which are naturally manures to each other, must render a railroad passing through them, highly beneficial to the agriculture of the adjoining districts ; and I have no doubt, but that by the agency of one railroad or other, the chalks of Sussex will, eventually, be exchanged for the stiff clays of the Weald of Kent, to an enormous extent, since they are both so fertilizing to each other. In the same manner will the limestones of Somersetshire be mixed with the strong clays of the same county and Devonshire, by means of the Bristol and Exeter Railway. But it is needless to multiply the instances of the certain results which will be obtained by the use of railroads, in the fertilizing exchange of soils.

To the lover of strong facts, I would refer the case of that portion of Chat Moss, now rapidly bringing into cultivation, by the side of the Liverpool and Manchester Railway, and entirely by the means or influence of that great work. The stranger to that district, cannot imagine a more desolate or absolutely barren tract than this moss, which contains several square miles. It is sterile from its soil being composed almost entirely of hungry, inert, vegetable remains, saturated with water and salts of iron. It is, in truth, a trembling, peaty bog, tenanted only by the commonest heath plants, and even these struggling for existence. The farmers of Lancashire knew full well the cause of its sterility, and its cure; that clay or lime, or both, spread liberally on the surface, would speedily render it fertile; for it was only the excess of vegetable matter and its deficiency in the earths, which rendered it barren; but the expense of their carriage was an insuperable obstacle. The traveller by the railway now sees, in the very middle of this great bog, well cultivated and neatly arranged fields, flourishing crops of oats, wheat, and potatoes; farm-houses and cottages erected, earth-spreading, ditches opening, and the ploughman profitably employed, where, a few months since, silence reigned undisputed; plantations of trees even are growing luxuriantly; and the fields have acquired a far greater solidity than could have been reasonably anticipated. Yet the hollow nature of this moss may be estimated from the fact, that it was with some difficulty

that the engineer of the railroad, Mr. Stephenson, was able to secure a foundation for his works. An attempt to drive piles through it was abandoned in despair: they were swallowed up in the course of a single night.

It is by availing himself of such improvements in the arts and sciences, that the farmer can alone hope to keep pace, by increasing the fertility of his soil, with the demands of a rapidly multiplying population. And it is from a thorough conviction of the important advantages which can be easily derived from a proper attention to the composition of soils and their fertilizers, that I have so often ventured to appeal on behalf of the investigation to the cultivator. It is a question too, of even national importance, since every step towards improvement tends to render the country more and more independant of foreign supplies. I feel that little has yet been done in this way compared with what will be hereafter accomplished. Yet it must be obvious to the most listless observer, that much has been effected by the English farmer in nearly keeping pace with the enormous encrease in population of the last half century. That population may, perhaps, have doubled in that period, and still in years of average produce, it is almost certain that the land yields sufficient, by the improved modes of cultivation hitherto adopted, to supply all its children. Let not, however, the cultivator believe that the resources of science are nearly exhausted ; the experience of ages must prove to him that the advances which

have been hitherto steadily making in the cultivation of the earth, have not yet given any indications of such a result. As the advance is made—as the mass of knowledge is increased, so is the field for further improvements proportionately enlarged.

THE END.

LONDON :

PRINTED BY BLATCH AND LAMPERT, GROVE PLACE, BROMPTON.

